Behavior Based Safety for Good Working Environment in Wind Power Generation: Case of Moroccan Onshore Wind Farms

Mohamed Younes El Bouti, Mohamed Allouch

Abstract— The high uncertainties and fluctuations in power generation present a big challenge in Morocco, particularly in wind power. However, a plethora of risks involved in wind industry processes that potentially may affect the crew's and environment safety and lead to severe accidents occurrence. Over than half of the work accidents took place as a result of the failure of human behavior in the workplace. Thus, this study adopts the Behavior-Based Safety (BBS) method using a survey questionnaire of a five-point Likert scale to assess workers' safety behavior and highlight the change patterns of the influencing factors on workers' Safety-Related Behavior (S-RB) in the existing operational Onshore Wind Farms (OWFs) which produce 47% of current wind energy (WE) in Morocco. The study emphasizes that the job factors are the most affecting ones regarding the workers' S-RB of all other analyzed factors on workplace safety performance, especially "the workplace conditions" which were disclosed as the major influencing factor on S-RB in all the assessed OWFs. All the identified measures will effectively treat the S-RB influencing factors encountered in order to lessen or eliminate wind farms accidents (WFAs) by changing workers unsafe behavior to safe behavior.

Index Terms— Control measures; Onshore wind farms; Influencing factors; Safety-related behavior; Wind farms accidents.

1 INTRODUCTION

RENEWABLE Energy is a clean energy since it produces no air, water, or thermal pollutants, and emits no greenhouse gas emissions [1]. Beyond climate change mitigation; RE can offer great advantages in terms of energy security and savings on combustibles imports and on energy imports, which benefit the local economy [1]. Likewise, RE offers job opportunities higher than any other energy industry such as nuclear and Oil/ Natural Gas and Coal [2]; hence, the number of workers employed in WE sector is increasing in the world which makes the occupational safety and health (OSH) become a major concern. On top of that, many previous studies as well as accidents statistics have corroborated the safety challenges and the high risky working environment that the WE sector knows [3], [4], [5], [6], [7], [8]. It is obvious that industrial accidents lead to enormous distress among all those who are concerned within an organization. Therefore, it is important to have in place adequate systems to effectively manage the risks and prevent WFAs [9]. However, most of the control measures tackle only the typical hazards of a WFs (Wind Farms) project lifecycle whereas, the analysis of human factors and workers' behavioural safety and their relationship with WFAs remain a major gap in work risk assessment as well as in the accidents' root cause during the investigation process. Many studies confirm that over than half of work accidents refer to the failure of human behaviour in the workplace [10], [11], [12], [13], [14]. In order to hinder occupational work-related injuries, illness and accidents; all of which can cost company money, reputation, and potentially their businesses continuity [15], the analysis of human factors and managing human failures must thus be dealt with during the whole lifecycle of operation and maintenance of OWF [5], especially in developing countries where human factor has greater influences on human failures [10]. Many researchers have tried to tackle the occupational accidents issues where there is a good understanding of the patterns of the occurred accidents in the WE sector; however, there are only limited studies on the behavioural safety analysis (Behaviour-Based Safety [11] for accident prevention. In Morocco, no analogous study has been conducted previously to analyses workers' safety behaviour in this particular sector despite the fact that the country has the highest fatal work accident rate in the region of the Middle Eastern Crescent [16]. Furthermore, Moroccan government has set a target of 42% total share of RE in the energy capacity to be installed by 2020 [17]. To meet this target, the country plans to increase the installed hydro capacity to reach 2000 MW and take advantage of the country's excellent domestic solar-wind resources [18] to develop 2000 MW of solar capacity and 2000 MW of wind capacity. As a result, this wind project will employ more workers as the country will have the largest installed wind capacity in Africa [19]. Yet, the skills and experience shortage may pose risk because the Moroccan worker will definitely be involved in such new perilous working conditions. Based on this challenge, the objective of this study is to tackle the root cause of the potential accidents by:

- providing an in-depth and comprehensive overview of human factors that influence the S-RB of the Moroccan WFs' workers during the maintenance activities,

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➢ introducing the appropriate control measures in order to curtail the relevant risks that can emanate from unsafe acts to an acceptable and feasible level,

➢ enhancing the quality and safety environment in the workplace of the OWFs.

Although WE is considered a more environmentally friendly energy source than any other sources, this does not necessarily mean it will be good for the Health and Safety (H&S) of workers as well. As WE industry continues to grow all over the world, new challenges begin to emerge (Figure 1).

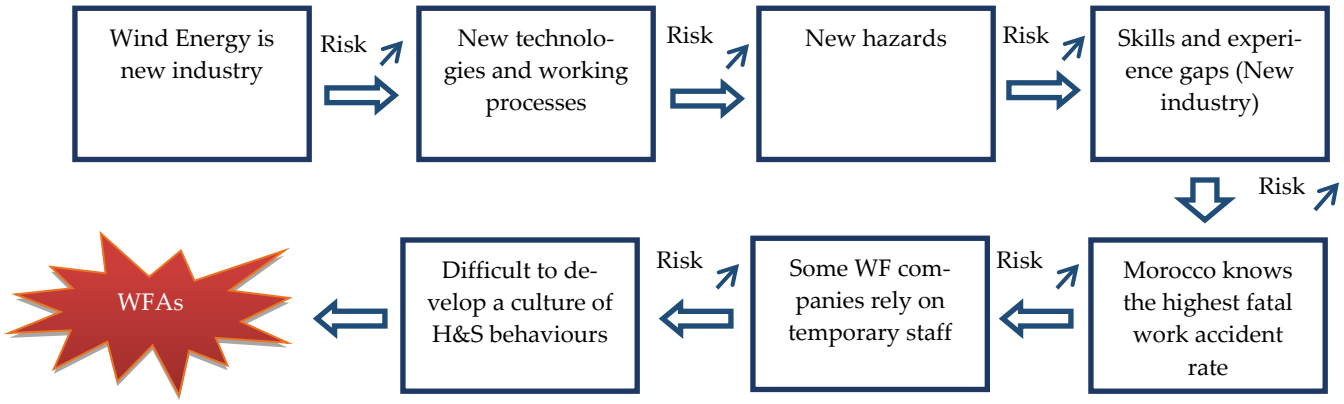


Fig. 1. Overview of wind energy challenges in Morocco.

TABLE 1. PROPOSAL OF HYPOTHESES FOR TESTING

N°	Hypotheses
H1	*"The environment: the workplace conditions" in OWFs are the most influencing factors on the workers' S-RB.*
H2	*"The workloads" in OWFs impact workers' S-RB and can lead to human failure.*
H3	*"Knowledge" affects the human reliability in the workplace and is responsible for safety performance at the site.*
H4	*Workers' "experience" has a significant relationship with the human reliability and work accident in the OWFs.*
H5	*"Management commitment and leadership" has a greater effect on workers' S-RB.*
H6	*"Keeping up-to-date with legal requirements" assists the WFs' workers to adapt their behaviour in compliance with H&S standards.*
H7	*"Effective communication of information" is a vital tool to improve workers' S-RB.*

2 LITERATURE REVIEW

2.1 Human Factor and Their Influence on Wind Farms

Human factors can lead to H&S issues in the WE sector such as short-term sprains and fatigue as well as long-term injuries, particularly backs and knees. These human factors can negatively impact workers' performance by encouraging them to assume awkward body postures or take unsafe shortcuts to complete a task, which may result in entanglement in the machinery or broken bones, lacerations, face contusions and amputation [3]. It has been proven that the root cause of the failure mode in some maintenance activities in WF is the human factor [20]. Similarly, transportation incidents in the wind power industry are caused by human-related behaviour [8]. Many factors impact the safety of WFs' workers. Yet, when it comes to workers' safety, the most critical element to comprehend is the "human factors" [21] since they directly or indirectly affect the performance and safety of WFs [22]. Heinrich has affirmed that 88% of work accidents are the proximate causes resulting from workers' unsafe acts, 10% are unsafe conditions and 2% are unpreventable accidents [23]. Moreover, the failure of the international standards which do not focus on the "human factors" in the working environment when developing and putting in place the desired process and procedures may also be considered an additional burden [24].

2.2 Why Behaviour-Based Safety Method?

Making a working environment safe is about more than eliminating hazards and setting up safety procedures. In fact, it is about people and their attitudes, how they behave, feel

and think towards safety in the workstation. People play a crucial role in making the workplace safe as substantiated in previous studies:

➢ In 1931, Heinrich, in an experimental finding, stated that for every accident in a workplace that causes a major injury, there are 29 mishaps that cause minor injuries and 300 mishaps without injuries (Figure 2) Graphs, drawings, etc - 800 dpi preferred; 600 dpi minimum [25].

➢ In 1969, inspired by Heinrich work, Frank E. Bird's empirical finding, which was based on Unrestricted interviews with supervisors of incidents that occurred under slightly different circumstances, showed afterwards that 600 incidents led to one major accident; which means that for every single fatality, there must be assumed a hidden bottom end of the pyramid of 600 minor incidents without any negative consequences (Figure 2) [25].

In 2003, based on H.W. Heinrich's original work, Conoco Phillips Marine conducted an analogous study in which he demonstrated a big difference in the ratio of fatal accidents & near misses (Figure 2). The Conoco study revealed that for every fatality, there are at least 300,000 at-risk behaviours defined as activities that are not constantly conforming to safety rules such as taking shortcuts in the workplace and bypassing safety components on machinery and so forth [25].

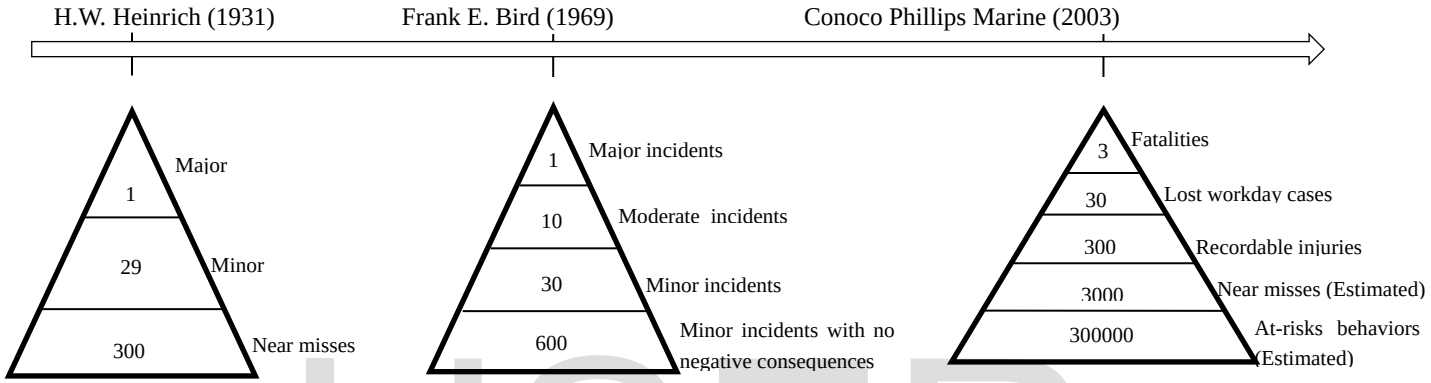


Fig. 2. Heinrich accident pyramid and similar studies.

At-risk behaviours (are):

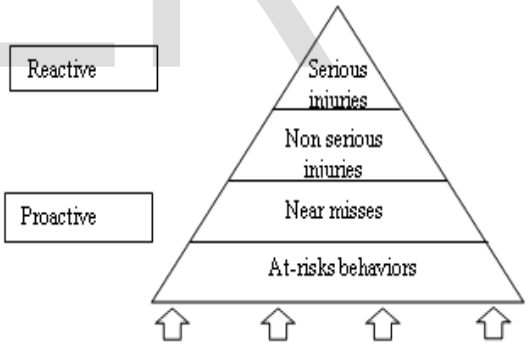
➢ often more convenient with workers' objectives, easier, comfortable, save time because they are faster than safe behaviours,

➢ often reinforced by the work culture,

➢ rarely result in negative consequences (e.g. injury, accident, reprimand). Meanwhile, they could eventually lead to a fatality,

➢ the last observable and measurable ones in the workplace prior to the occurrence of undesired events (Figure 2).

An issue of paramount importance to H&S management is the way that the employees behave. Attitudes are inside workers' head which can be seen through their behaviors in the workplace. They are observable or measurable not when they were just ideas and feelings, but when these attitudes become acts and behaviors (Figure 3) in daily work business. Here is where the BBS method can be implemented in an attempt to alter workers' attitudes by changing their unsafe behaviors to safe behaviors in the workplace during proactive phase and thus, the safety performance will improve through controlling the latter before resulting in injuries.



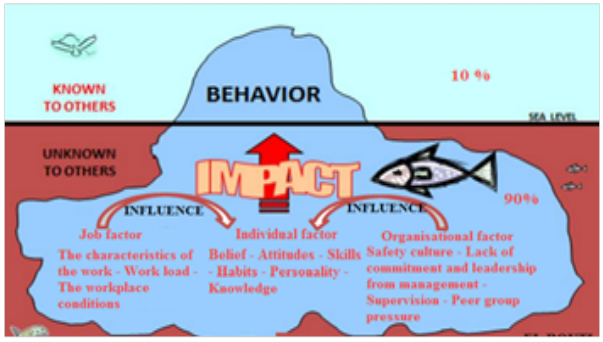


Fig. 3. Diagram of the impact of contributing factors of human failure on workers behavior

2.3 Causes of human failure

After an accident involving human failure, an investigation into the causes and contributing factors is very often conducted in order to understand why and how the human failures occurred in the workplace. However, finding out the causes of an accident is essential to stop similar accidents from reoccurring. Multi causation theory [26] argues that for every unsafe act, injury or accident there may be many contributing factors and causes. In this study, we grouped these causes of human failure into three main contributing factors; Individual, Job and Organization factors. Yet, human failures do encompass human errors and violations (Figure 4):

- Human error is a decision or an action which was not done deliberately by the worker, however, it involved him in an intentional or unintentional deviation from an approved rule, procedure, standard, and which may result in an undesirable event in the workstation [26], [27]
- Violation is any deliberate swerve from the rules, procedures, instructions and regulations, which are considered requisite for the safe or effective operation and maintenance of WFs or equipment [26], [26], [27].

Errors categorized into three aspects: slips, lapses and mistakes. Slips and lapses happen in routine tasks with workers who know well their work process or those who are experienced in their work which allows them to perform the task without much need for conscious attention. These tasks are called 'skill-based errors' and are very fragile to errors if the workers' attention is swerved, even immediately. However, mistakes are inadvertent errors and are a more difficult type of human error where the workers do the wrong thing believing it to be the right way [26], [27]

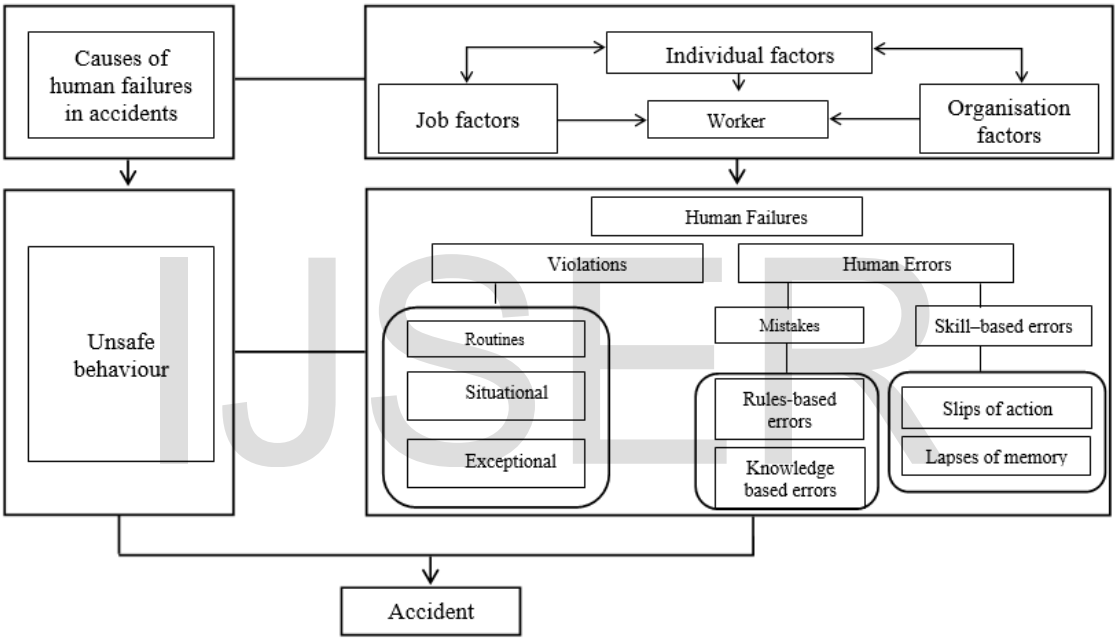


Fig. 4. Diagram of failure of human factors

3 Materials and Methods

In order to look at how human factors influence safe working practices in the workplace, we should first understand why workers behave the way they do at work. To remediate unsafe behavior, we should remove the cause of that behavior and this will call for identifying the causes of human failure through survey questionnaires in WFs.

3.1 Pilot Study

In this study, the implementation of BBS (Figure 5) within the OWFs will assist to observe, analyse and measure workers' safety behaviour through a list of contributory factors, demonstrating situations where workers' S-RB could be affected. As a result, the human failure and a potential mishap can occur. The final list of assessment factors was later embedded into a questionnaire so as to gather the tendency of opportunities for improvements and reduce the likelihood of an accident which may occur due to one factor or combination of those factors. Thereafter, the questionnaire was distributed and self-assessed by each wind project representative (Safety practitioners, the project responsible, and maintenance technicians) with continuous support via remote follow-up. Our study endeavoured to involve independent local assessors who better know the site processes and are closer to the workers in daily business in an attempt to accurately observe the influencing factors on the workers' S-RB and suggest the corresponding mitigation measures to effectively overcome and tackle the identified causes of human failure that may lead to certain H&S issues. In this study, the discussion will focus on the three first significant influencing factors for each assessment area.

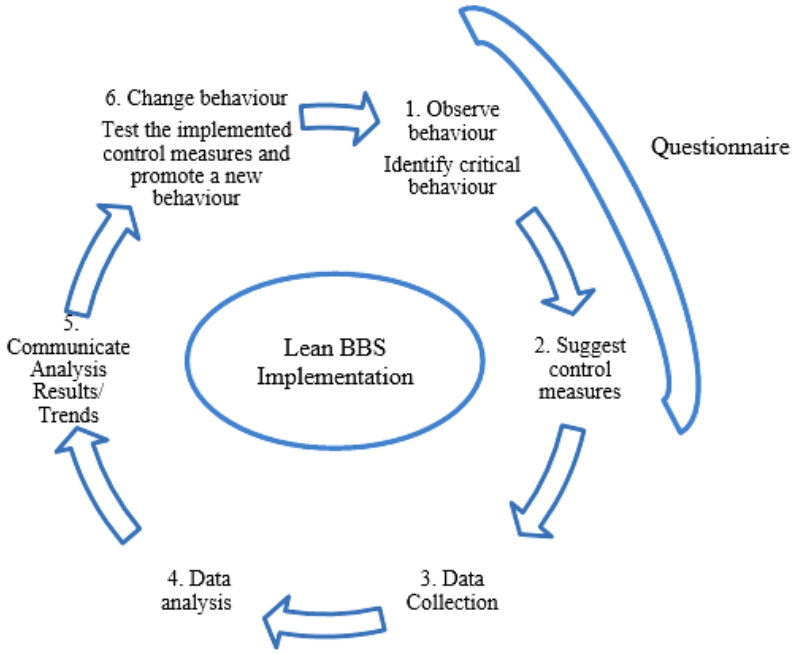


Fig. 5. Lean BBS implementation

3.2 Identification of Survey Items with Related Hypotheses

The S-RB influencing factors, which were determined from different guidelines of human factor in OSH [28], [29], [30], [27], [31] as well as from the relevant articles [10], [32], [33], [34], [35], [36], are deemed as leading factors of human failure in the workplace. These factors were picked based on their relevance to the energy industry, processes and work environment, classified as causes of human failure and antecedents of safety performance in the workstation. Having identified them using literature review, the survey items were approved of and ameliorated through consulting various EHS (Environment Health and Safety) and industrial technical experts providing their feedback on the questionnaire survey and converged aspects which were afterwards combined and rectified. The factors were deployed in the pilot study based on the Cronbach's alpha of the survey items against which each cause of human failure was calculated. Cronbach's alpha was used to measure internal consistency and reliability of the assessed factors, and to show how closely related a set of items are as a group. It ranges from 0 to 1; thus, the value of the Coefficient: ≥0.9 indicates excellent inter-items consistency, ≥0.8 indicates good consistency, ≥0.7 indicates acceptable consistency, ≥0.6 reflects questionable internal consistency, and ≥0.5 indicates poor and inadmissible consistency [37]. In this study, Cronbach's alpha yielded 0,925 which is an excellent inter-items consistency indicating that the items were consistent in measuring the intended.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
0,925	0,944	26

Table 2. Reliability statistics – retention variables

3.3 Population Study

The BBS program was conducted in five existing operational OWFs distributed over the northern and southern of the Kingdom of Morocco with different capacities, however, they produce 47% of total actual WE in the country [38]. The enquiry addresses all the involved workers during operation and maintenance of OWFs. The questionnaire highlighted various causes of potential human failure. These samplings of OWFs were selected in different regions of the country in an attempt to get data which present a result that can be adopted afterwards in the forthcoming OWFs across Morocco [17]. The rollout of the questionnaire survey has been performed using different methods (telephone, emails, and direct meetings) to communicate and explain the aim of the study for each wind project representative and the threshold of each single assessed factor. Afterwards, the same method was used to present and interpret the final outcomes. This focused achievement has been promoted by the reliability and accuracy of the obtained outcomes across all the five evaluated OWFs. They have a similar paramount goal, which is the power generation to meet the needs of the country in very safe working conditions.

3.4 Survey Design

In the attempt to obtain precise, clear and practical results of the survey, the questionnaire structure encompasses 36 items; each item represents a cause of human failure divided into four different sections which give more opportunities to ameliorate safety management system from different approaches. Hence, the

first 26 items were related to the influencing factors on workplace safety performance, were embedded into 3 main sections (Individual, Job and Organization), and afterwards were evaluated by each OWF assessor. The first section assessed 8 items related to the individual and their personal characteristics. The second section assessed 5 items concerning the job; the task that the workers carry out. The third section assessed 13 items regarding the organization and their characteristics that the employees are working for. Furthermore, the last fourth section gives 10 proposals of control measures for workplace safety improvement that can be implemented in the assessed wind projects. The five-point Likert Scale (from one for "strongly disagree" to five for "strongly agree") [39] was deployed in this questionnaire for each survey items, which gives the chance to the evaluators to provide the extent of their approval and endorsement with the given statement.

4 Results and Discussions

In this section, the results are illustrated through the line graph in figure 5 which shows the extent of how the workers' S-RB in OWFs can be influenced by the impact of the assessed factors that could lead to human failure in the workplace. Nevertheless, the degree of the incidence varies depending on the combination of various factors and the extent of how those factors affect the working environment safety. Moreover, safety management consists of a range of formal and informal different elements (Figure 6 underneath) that all aim to improve H&S performance for accident prevention in the WFs. However, it is equally important to think about conceptual solutions for improving workers' S-RB. Thus, all the assessed control measures are intended to improve the manpower's S-RB in the WFs, just with a different effectiveness rate of each assessed measure which varies depending on the type of activity carried out, risks relevance, H&S issues, encountered hurdles, as well as cultures, beliefs, and practices regarded as a hindrance that differs from a country to another [40].

4.1 Contributory factors influencing workers safety behavior patterns in operational Moroccan wind farms

As expected, the study emphasizes the hypothesis H1 illustrating that "the environment: the workplace conditions" where the workers conduct their tasks are the most contributing factors to the human failure in OWFs. This finding is mainly associated with the sector of industry under scrutiny in this paper. Also, its relevance to the nature of the conducted activities as the common wind turbine workstation is often in the nacelle [41], which was defined in the previous study as a confined space [6]. Within this context, the maintenance staffs are always required to access the workplace to carry out their maintenance tasks despite involving operations which may expose workers to miscellaneous risks such as, climbing up very tall vertical ladders throughout the turbine tower which is at the height of 80 meters depending on turbine type. This may result in fatigue, fall from a fixed ladder, contact with the falling objects from above, or forgetting working tools to be taken to reach to their workplace. The nacelle is the place where other types of risks may occur such as manual handling [30], awkward working postures [41], being trapped between objects or contact with the hanging objects, swinging objects or moving parts of the machine during maintenance, slip trip, falling on the same level, or on a stationary sharp objects. Inside this confined space, the workers can also be exposed to the hazardous substances, fire risk while working near to or handling flammable products, high temperature or toxic fumes, which can arise from heat or existing volatile organic compounds used normally for lubrication. Yet, the workstation in wind turbine can be outside of the nacelle for blade maintenance to avoid cracks propagation [42]. Working at height exposes the workers to the risk of falling from the height, particularly during strong wind [41]. Furthermore, in the WFs projects the work supervision is hard due to the difficult access to the workplace; thus, there is no direct supervision of work unless the supervisor climbs up to the nacelle after notifying the maintenance crew [41]. One of the main challenges while working on OWFs is the transportation of workers because WFs are often located in remote mountainous or desert areas, far from cities in areas that are not easy to access [1], [8], [43] where the wind speed is continuously high. Thus, the workers are obliged to travel on daily basis before commencing their work. This exposes them to the risk of tough roads of the desert and mountains as well as the risk of fatigue which may affect their H&S performance at work, especially while coping with such hazardous workplace as substantiated previously [3], [4], [5], [6], [8]. Likewise, if the emergency rescue plan is not considered in those OWFs situated in remote locations, the safety of the workers; on the one hand, will be at further risk; that is to say the workers themselves will be under more pressure which may affect their psychology during the work, especially in the case of remote areas, which are short of hospitals; but on the other hand, the rescuers may find difficulty reaching and rescuing the victim from the accident place in the right time, particularly from inside and outside the nacelle. When the workplace conditions are unsafe or difficult to ensure H&S, human reliability can be negatively impacted leading to a potential human failure [44], [14], [45], [46]. In other words, if control and management of the working environment parameters are poor, the workplace conditions will worsen and become unsafe as well as accidents can easily occur [46]. The workplace should, therefore, be provided with all the design features required to ensure safe and healthy working conditions [41], otherwise, workers may find ways of working that are not necessarily safe, their performance may consequently degrade with the poor workplace conditions because they directly affect workers' health behaviours [1], [49] as well as their safety in the workplace [48]. For Mearns, the workers' carelessness (Human Behaviour) leads to unsafe working conditions [49].

By the same token, the line graph in Figure 5 shows that the study corroborates the hypothesis H2 that the "workload" is regarded as the second potential cause of human failure in the workplace of Moroccan OWFs. Thus, the workload has a significant relationship with workers' S-RB since it contributes to human errors and situational violations in the workplace as confirmed in previous studies [27], [50]. The duration of maintenance work per year is relying on the wind turbine type and age, thus the older a wind turbine gets, the more maintenance it needs [41]. This means that the more the WFs become older, the more maintenance is required. However, if the

management does not consider putting in place sufficient resources, be it for operation or maintenance after commissioning. The amount and rate of work, deadlines and variety of unscheduled corrective maintenance work that the manpower has to deal with will consequently lead to fatigue and burnout of the workers, including work-related stress, health depression, workers' anxiety and time pressure. This outcome, as substantiated in the previous findings [27], [50] discloses that the workload affects human reliability as result of its impact on workers' S-RB [51], making of it the root cause of many occurred accidents [51], [54].

By returning to the hypothesis H3 set at the beginning of this study, it is possible to state that the workers' "knowledge" is sharply influencing their behaviour in the workstation with a similar impact rate of "the workload", as displayed in the below line graph (Figure 6). This finding may explain the fact that OWFs industry in Morocco is still newly developing [19]. The maintenance crew may involve sub-contractors for a limited period of time to mainly conduct preventive maintenance, since the majority of the newly installed wind turbines do not require extensive critical maintenance; thus, they are not compelled to maintain permanent technicians at site, which means that the temporary sub-contractors, who are more involved in work accidents [4], may be competent in terms of technical part, however, they have less knowledge regarding H&S at work, particularly in wind industry in Morocco.

Or, it can sometimes be as a result of a cost-saving management decision since H&S or technical knowledge needs a particular training in the offshore manufacturer training centre in order to qualify the workers to carry out their daily activities at site safely [8]. Hence, this qualification process will be costly, especially if the required qualification is a subject of a periodically refreshing training for a group of workers. However, knowledge remains essential in the workplace, for it allows the workers to be able to faultlessly evaluate risk [31] before and during the work; otherwise, the risk will be missed during the risk assessment phase and consequently no control measure will be put in place and the safety of the workers will be at risk. Likewise, lack of H&S and technical knowledge lead to the workers' poor risk perception; that is to say, accidents will undoubtedly happen. In order to fully understand H&S issues, reveal non-conformances and propose solutions that may apply in the workstations before an undesired event occurs; the crew should be familiar with standards, procedures, legal requirement, and all technical and H&S information associated to the WFs. Potential strengths and weaknesses of several options and solutions may solve the problem; however, finding a solution to a specific H&S problem is sometimes difficult, because creating a safe working method requires extensive background knowledge [53] and an awareness of the likely consequences of the different actions that are available.

The conducted survey questionnaire across the five operational Moroccan OWFs has interestingly illustrated in the underneath line graph of figure 6 that "experience" is the fourth contributing element to the human failure which seemingly influences the Moroccan workers' safety behaviour with the same impact rate of "the workload" and the workers' "knowledge" previously discussed. This outcome corroborates our hypothesis H4. It is quite hard to find experienced workforces in a country where such WE industry is newly developing; especially the latter poses multiple hazards for the inexperienced Moroccan manpower in this industry. Even though there has been a big flux of workers to the WE sector, many of them are inexperienced in the field, have little experience of working in WFs as well as unacquainted with the H&S challenge that they will face [8]. However, such hazardous working environment in WE [3], [4], [5], [6], [8] requires experienced and well-trained workers in the same field of the industry since a positive work experience brings to job contentment and encourages physical and mental well-being [27]. Lack of experience generally makes the worker more vulnerable and exposed to risk in the workplace. However, a newly qualified person may perform tasks more carefully than an experienced worker [31]. If we consider the work experience associated with workers' age, it has been proven in the previous study that young workers have higher non-fatal injuries rate than older workers [54]. Another earlier research emphasizes that the rate of work accidents is higher for experienced persons, having less than 4 years in the same position [55]. In some cases, the workers' experience distorts their risk perception in the workplace; therefore, the risk increases [31] and leads to error-producing conditions [50]. Therefore, work experience is a double-edged sword, affecting or improving the workplace safety through its impact on the workers' S-RB by making the experienced workers reach a level of confidence in the workplace to the extent of overlooking rigorous H&S requirements. Work experience can enhance safety in the workplace when the workers benefit from previous experiences and failures to make their workplace safe. Hence, it helps instil safety culture paradigm within a company [53].

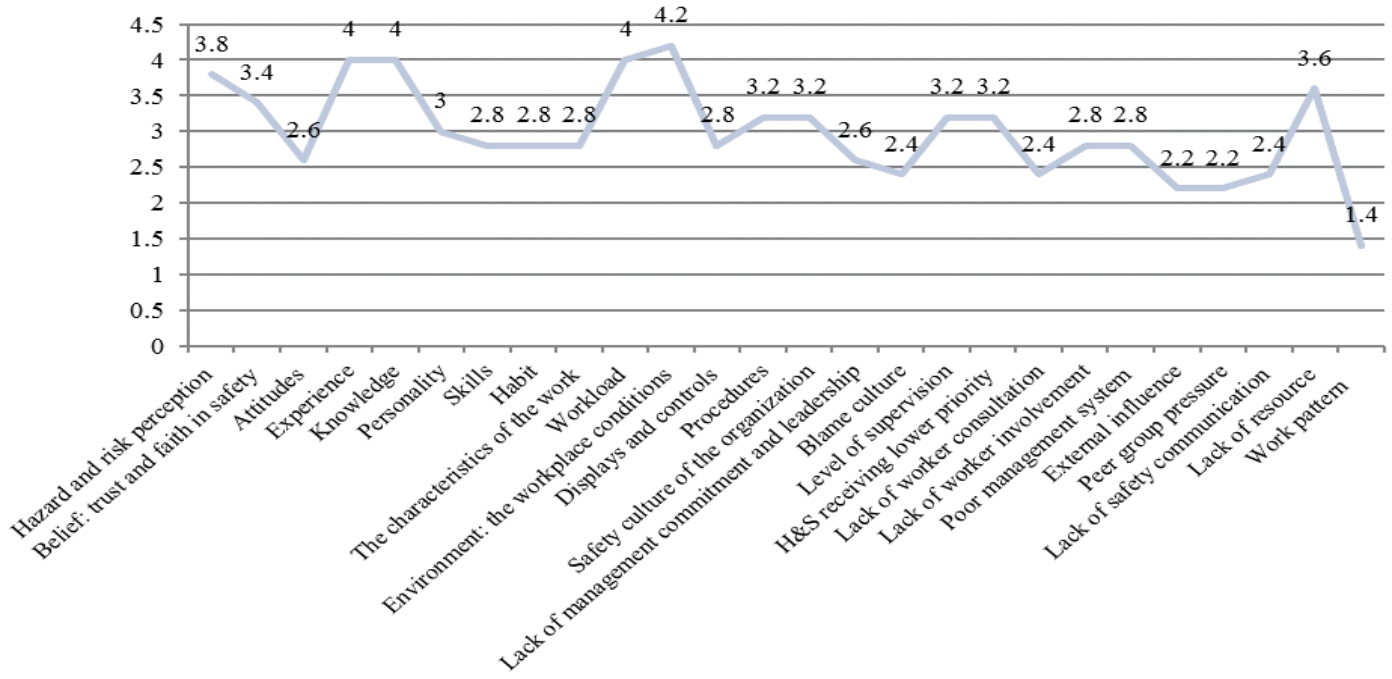


Fig. 6. Assessment results of contributory factors in influencing workers safety behavior pattern in a sampling of operational Moroccan wind farms

4.2 Safety management control measures against the identified workers' safety-related behavior affecting factors in Moroccan wind farms

From the underneath radar graph in figure 7, it is crystal clear that the "Management commitment and leadership" is the most striking measure that has an important effect on the five assessed WFs. This result substantiates the hypothesis H5 which is regarded as the most appropriate preventive action to effectively tackle safety non-compliances by changing workers' unsafe behaviour to safe behaviour. A successful business today requires a total engagement from responsible persons within the WFs. Commitment should start from top management who must provide sufficient leadership to motivate and inspire other managers at all levels to rigorously follow H&S objectives and drive up the performance of safety [36], [57]. In this way, commitment is cascaded down through the organization from very top to the shop floor workforce. An important factor in demonstrating management commitment resides in a visible and credible leadership [8]. Managers must show their commitment to H&S to their staff through a strong realization of safety compliance [36] which has a greater impact on EHS culture and workers' unsafe behaviours. To enhance safety performance as well as accident reduction, the workers' unsafe behaviours should be changed via the motivation to comply with H&S rules, policies of the organization [10], [3], [58], [59]. Owing to the remote locations of WFs, such management engagement is essential to be considered directly or indirectly on a regular basis to promote the safety culture among workers instead of getting the feeling that nobody is taking care of their safety.

The underneath radar graph in figure 7 underscores the hypothesis H6 that "Keeping up to date with legal requirements" has been rated by the most of the assessed WFs as the second most effective preventive action in an attempt to protect the site from workers' unsafe behaviour and reinforce their safe behaviour to avoid potential WFAs through complying with relevant legal legislation. However, this compliance requires up-to-date knowledge of the relevant legal standards, generally described as the H&S obligations. There are different ways by which the WFs and workforce can stay up to date with the H&S legal requirement, including ministry website, electronic newsletters, contracted external services and so on. This is an essential part of the planning process to consider the following approaches:

- Identification and compliance with relevant legal requirements.
- An implication of relevant legal requirements into the H&S Management System.
- Evaluation and review of relevant legal requirements on regular basis.
- Access to relevant legal requirements and information.

This legal legislation places an onus on the employer to ensure that workstations, work equipment, work activities and hazardous materials are reasonably controlled, safe and without risk to health. What is more, these legal requirements place a duty on the workers to look after their own and other workers' H&S. However, there are various barriers to raising H&S standards in the workplace [31], particularly in the remote location of WFs where there is lack of direct supervision [41] of the maintenance activities within the hazardous working conditions. Despite the fact that the law may not go into H&S and technical details of WFs activities, it enforces the basic requirements to be complied with to ensure that the site activities and relevant risks are under control of safety management system. This may influence positively the employees' behaviour in order to improve H&S performance within WFs. This is the role of enforcement agencies as is the case with Morocco where the insurance companies, private contracted companies, an internal committee of the organization as well as Ministry of Labour are responsible for enforcing the H&S law, carrying out inspections and audits on a regular basis.

The majority of those surveyed WFs have confirmed that both "Keeping up to date with legal requirements" and the "Effective communication of information" have a similar impact on work-

ers' unsafe behaviour. The radar graph below (Figure 7) shows that the "Effective communication of information" is one of the first three selected effective measures that can enhance WFs workplaces safety by changing unsafe behaviour to safe behaviour as hypothesized in H7. Because of the fact that this preventive action has a dramatic impact on workers' S-RB, especially in remote locations of WFs, a successful project management will, therefore, depend on how the extent of the safety information is being communicated to the concerned employees [8]. Communication can be defined as the process of transmitting information from a sender to a recipient (employees) in order that the correct information has to be delivered, received and comprehended [31]. This concerns all relevant H&S information, including safety training, WFAs lessons learnt, new safety topics, work risk assessment, procedures, non-conformances, audit results, legal requirements, near misses, incidents, safety observations, safety improvements, H&S action plan and so on. Preferably, to effectively cope with the risks, the wind project should use different communication methods (meetings, interviews, training sessions, pre-job briefings, and awareness or it can be transmitted remotely when the need arises by using various communication tools) to convey H&S messages and information to the workforce, and check if those messages are well understood in an attempt to ensure minimum basic safety knowledge in place. Good communication makes the workers be aware of and well-trained in coping with relevant risks and hazards within the WF workplaces, particularly in emergency situations; therefore, it is necessary to change their attitude over time, reducing the risk to an acceptable level [8] and improve workers responses to such contingencies situations. It was revealed that effective communication has a positive connection with safe behaviours resulting in accidents reduction as well [60]. Without safety communication, workers try to do their jobs to the best of their ability, but they do so either by informally copying others (including copying all the bad habits and unsafe working practices that they see) or by doing the job the way that they think is best. Furthermore, the previous studies revealed that poor communication was an underlying and immediate cause of many previous incidents [27], [61], [30].

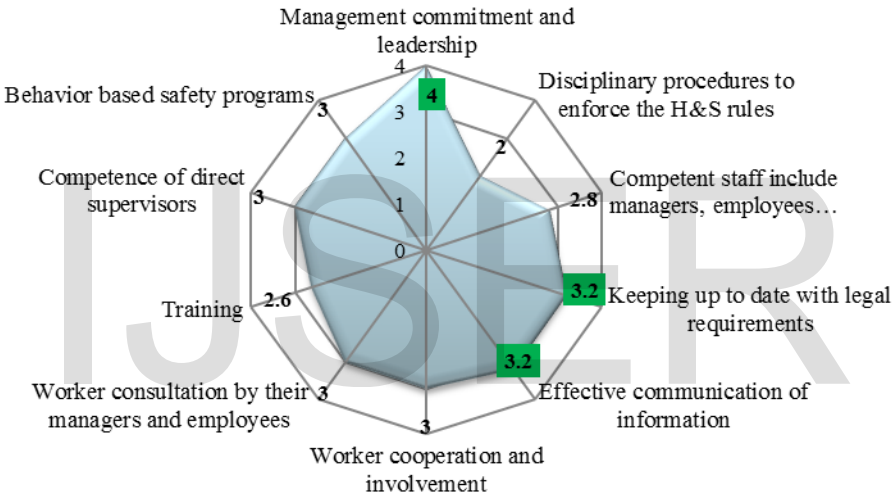


Fig. 7. Rating results of the control measures completed by Moroccan wind farms representatives

From bar graph below of the figure 8, we can say that tl job factors which consist of the nature of the task, workloa the working environment, the design of displays and control and the role of procedures that the study assessed in all tl five WFs have a greater influence on workers' S-RB than tl other assessed factors. This outcome underscores the previou finding that the nature of activity within the operational Wl is deemed as high-risk activities, requiring effective contr measures in order to minimize or eliminate any unsafe behaviour that may be produced by the workers in the workplace as is the case with the wind sector which is regarded as a hazardous working environment [3], [4], [5], [6]. However, the impact of all the assessed factors on the workers at work not only affects their H&S, but it also affects their productivity and efficiency. Besides, all the proposed hypotheses of this study are accepted.

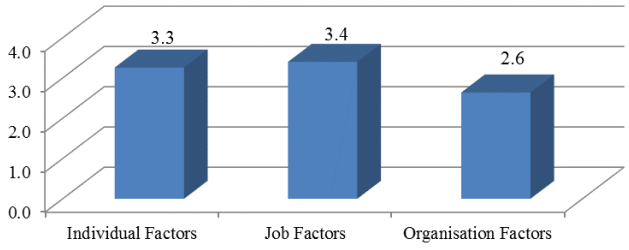


Fig. 8. Overview of rating results of the assessed human factors in a sampling of operational Moroccan wind farms

CONCLUSIONS

Parts of this paper are based on a practical experience, implementing BBS at sites. There is a shortage of scientific researches to study human factors for OSH in the WE as well as what is required to ensure a good H&S in OWFs, which is partly explained by the novelty of the industry nationally and internationally. Nationally, this green investment is newly

rolled out in the different regions of the country [19]. This fact generates various contributory elements that may affect the H&S performance of the workers in WFs through influencing their S-RB, which subsequently lead to a potential human failure and put their H&S at risk. This paper has studied those elements which form the causes of human failure regarding H&S in the workplace. Hence, those elements have important guiding significance to lessen or prevent WFAs and the unsafe acts, which contribute to workplace injuries and losses as well as enhancing the workers' efficiency and energy production of WFs safely. All the analysed factors and control measures have a positive or negative impact on the workers' S-RB only with different rates depending on various criteria. BBS approach has obviously illustrated that the job factors are more affecting than the other analysed factors on H&S performance in WFs workplaces through their direct incidence, especially the "Environment: the workplace conditions" that the WFs is specifically characterized with. What is more, this finding was disclosed as the fundamental factor responsible for influencing H&S performance in all the five WFs. It is revealed that "Workload", "Knowledge", and "Experience" have an influence with an identical rate on the workers' S-RB in all the assessed Moroccan WFs. It is obvious that unsafe behaviour appears in the workplace in various forms – violation or/and human errors based on a combination of leading circumstances - each single generated behaviour has a different impact on workplace safety and requires adequate preventive actions. Therefore, it is important to ensure first that every worker in the WFs has sufficient and appropriate knowledge, experience and receives an acceptable workload - besides, the tasks should be designed in conformance with ergonomic principles considering both their limitations and strengths. Second, in order to effectively induce safe behaviours within WFs, "management commitment and leadership" has been proven in this study as the major workplace factor to enhance the OSH within WFs' workstations. Afterwards, both "keeping up to date with legal requirements" and "effective communication of information" were revealed as the second control measures with a symmetrical extent of impact to improve H&S performance. To sum up, in order to effectively tackle the WFs' H&S issues that may emanate from workers' unsafe behaviour, all the assessed factors and control measures should be taken into consideration during the implementation of the safety management system. In other words, the ultimate prioritization should be given to all the evaluated factors with different ratings as demonstrated in this study.

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